Original Article

Efficacy of Hemodynamic Monitoring in Cardiac Surgical Patients

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Background: Studies have shown that cardiac output-guided hemodynamic therapy reduces complications and length of hospital stay in the postoperative period. However, this strategy has variable effects in cardiac surgical patients at risk for low-cardiac-output syndrome (LCOS).

Objective: To compare the overall 30-day composite endpoint and hospital stay between conventional treatment (Group A) and cardiac output-guided hemodynamic therapy by institutional protocol (Group B) in postoperative cardiac surgical patients at risk for LCOS.

Materials and Methods: Sixty-five patients with 35 in Group A and 30 in Group B, that underwent coronary artery bypass surgery or valvular heart surgery between August 2018 and July 2019 were prospectively analyzed. In Group A, patients received standard protocol treatment guided primarily by mean arterial pressure and central venous pressure in the intensive care unit (ICU). In Group B, patients received treatment guided primarily by stroke volume variation, mean arterial pressure, and the cardiac index using the FloTrac monitoring system.

Results: The overall 30-day composite Group A and Group B endpoints were 62.9% and 46.7% (p=0.145), respectively. Group B had a lower occurrence of LCOS at 30% versus 37.1% (p=0.366), postoperative kidney injury at 20% versus 28.6% (p=0.424), and postoperative arrythmia at 20% versus 40% (p=0.082). Postoperative hemodialysis and postoperative mortality were higher in Group A at 5.7% versus 0% (p=0.184), and 2.9% versus 0% (p=0.351), respectively). Comparing both groups, there was no difference in length of ICU stay at 4 [3 to 5] versus 4 (2 to 5), (p=0.577) and hospital stay at 10 (9 to 130 versus 10 (9 to 11)(, p=0.201).

Conclusion: After cardiac surgery, cardiac output-guided hemodynamic therapy, compared to conventional treatment, insignificantly reduced the 30-day composite endpoint and length of hospital stay.

Keywords: Low-cardiac-output syndrome; Cardiac output monitoring; Goal-directed therapy

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With existing, modern advances in surgical techniques, myocardial protection, and perioperative care, cardiac procedure-related mortality has declined to less than 3%[1]. However, low-cardiac-output syndrome (LCOS), the most common complication, remains high and leads to tissue hypoxia, organ dysfunction, increased morbidity, and healthcare resource utilization[2].

LCOS includes a decreased cardiac index (CI) of less than 2 L/minute/m² within 6 to 18 hours after cardiac surgery[3]. The LCOS significant risk factors are the advanced age or older than 65 years, impaired LV function, and cardiopulmonary bypass (CPB) usage[4]. Optimizing fluid and vasopressors through hemodynamic monitoring is a LCOS therapy that can help detect and reduce postoperative complications[5].

Cardiac output-guided hemodynamic therapy has been shown in studies to reduce complications and hospital length of stay (LOS) in postoperative cardiac surgery[6,7]. However, this strategy has varying effects in cardiac surgical patients[8,9].

The present study investigated whether cardiac output-guided hemodynamic therapy in the postoperative period associated with improved postoperative outcomes in cardiac surgical patients at risk for LCOS, especially for elderly patients.

Materials and Methods

Study design

The present study was a prospective cohort study conducted using cardiac surgical patient data between August 2018 and July 2019 at Queen Sirikit Heart Center of the Northeast, Khon Kaen, Thailand.

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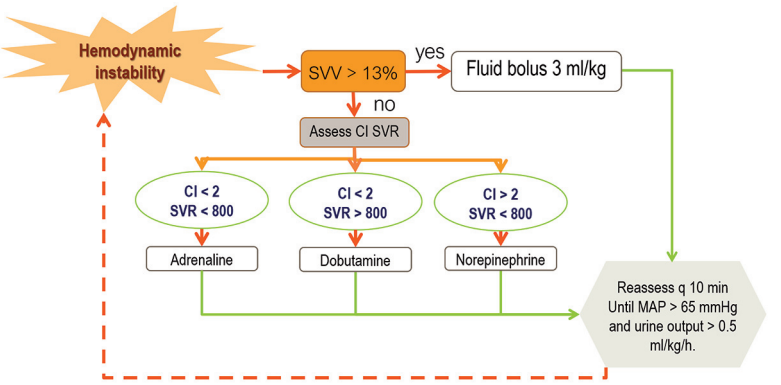

Figure 1. Algorithm of cardiac output-guided hemodynamic therapy (Group B).

SVV=stroke volume variation; CI=cardiac index (L/minute/m^2); SVR=systemic vascular resistance (dyn.s.cm^{-5})

The treatment protocol was approved by the Ethics Committee of the Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand (HE611101).

Patients

The present study consisted of 65 consecutive patients at least 70 years old and scheduled to undergo cardiac surgery using cardiopulmonary bypass and coronary artery bypass grafting (CABG), isolated aortic valve surgery, isolated mitral valve surgery, or any combination of these procedures. Patients were excluded from the study if it was an emergency surgery, a thoracic aortic procedure, or intraoperative extubation occurred, or congenital heart disease was present. Patients were also excluded if they had an intra-aortic balloon pump and required extracorporeal mechanical support. The study did not include patients who received operation from bleeding complication.

Protocol

Each study participant provided informed consent, and eligible patients were assigned, by surgeon preference, either as conventional treatment (Group A) or as cardiac output-guided hemodynamic therapy (Group B), which the patients received upon intensive care unit (ICU) admission through extubation.

After surgery, each patient was transferred to the ICU on mechanical ventilation. In both groups, patients were given a central venous catheter, an arterial line, and were monitored by echocardiography, pulse oximetry, invasive arterial blood pressure, and urine output.

Conventional treatment (Group A)

Hemodynamic management was based on institutional protocol interventions to achieve a central venous pressure between 8 to 12 mmHg. Interventions included fluid resuscitation with colloid or crystalloid bolus 300 to 500 mL, administration of inotropic agents with dobutamine and epinephrine, vasopressor with norepinephrine, and red blood cell (RBC) transfusion to maintain mean arterial pressure (MAP) greater than 65 mmHg and urine output remaining greater than 0.5 mL/kg/hour.

Cardiac output-guided hemodynamic therapy (Group B)

The CI was monitored using FloTrac (Edwards Lifesciences Corp., One Edwards Way, Irvine, CA, USA). Stroke volume variation (SVV) was managed through fluid bolus administration at frequent intervals as necessary to maintain an SVV of less than 13%. If required, a packed red blood cell (PRBC) transfusion was given to keep hematocrit higher than 30%. For a low CI and elevated systemic vascular resistance (SVR), inotropic dobutamine support was initiated at 5 mcg/kg/minute. For a low CI and low SVR, inotropic epinephrine support was initiated at 0.05 mcg/kg/minute. For a normal CI and low SVR, inotropic norepinephrine support was initiated at 0.05 mcg/kg/minute. Inotropic support was titrated to maintain a CI within 2.0 to 4.5 L/minute/m^2 and an SVR between 800 to 1,200 Dyn.s.cm^{-5} (Figure 1). The above hemodynamic parameters were monitored and managed according to the protocol continuously for 24 hours or until extubation in the ICU.

All patients received maintenance fluid to optimize MAP to greater than 65 mmHg. Hematocrit was maintained at greater than 30%, and PRBC was administered as required. Urine output was ensured greater than 0.5 mL/kg/hour, and patients

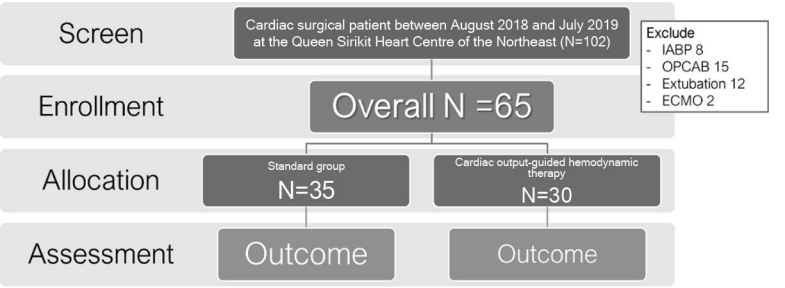

Figure 2. Study flowchart depicting the enrollment, allocation, and exclusion of the patients in Groups A & B.

IABP=intra-aortic balloon pump; OPCAB=off-pump coronary bypass; ECMO=extracorporeal membrane oxygenator

with hemodynamic instability received transthoracic echocardiography.

Study outcomes

The primary outcome was determined by comparing the overall composite endpoint of 30-day mortality and postoperative complications between the patients in Group A and the patients in Group B. Secondary outcomes were ICU and hospital LOS.

Data collection

Data were collected by the physicians in the Cardiac Surgery ICU. Patients were discharged from the ICU if their physiologic status was stable, they required no monitoring, and no further intervention was planned. Follow-up after hospital discharge was performed by the outpatient department clinic in person or via telephone until the thirtieth postoperative day.

Statistical analysis

The authors calculated sample size through a cohort study with the binary outcome equation, according to the methods of Maganti et al[10], who showed that the composite endpoint incidence was reduced from 30% in the usual care group to 1.3% in the hemodynamic-monitored group. The authors considered a 2-sided α-level of 0.05 and statistical power of 80%, and the equation revealed at least 30 patients in each group. The authors consecutively included 65 patients who met the criteria.

The quantitative variables were expressed as a mean with standard deviation (SD) or interquartile range (IQR) and compared between groups using the unpaired t-test. Qualitative variables were expressed as percentages and compared using the chi-squared test or Fisher's exact test. The correlation between variables were measured using the Pearson correlation coefficient or Spearman's rank correlation, as required. A p-value of less than 0.05 was considered statistically significant. Statistical analyses were performed with IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA).

Results

Of the 65 patients enrolled in the present study, 35 patients were allocated to the standard group (Group A) and 30 to the cardiac output-guided hemodynamic therapy group (Group B). Thirty-seven patients were excluded from the study (Figure 2). Across the two groups, the demographic data, comorbidity profile, and operative risk evaluation (EuroSCORE II and STS score) were comparable (Table 1), as were the perioperative data (Table 2).

In the first 24 hours following ICU admission, there was no significant difference in peak TNT, blood transfusion, and, based on the vasoactive inotropic score (VIS), inotropic usage (Table 2).

Outcome

The primary outcome was considered the overall composite of the 30-day endpoint, which was lower with cardiac output-guided hemodynamic therapy (Group B) at 46.7% versus 62.9% (p=0.145). Upon analyzing the primary outcome components, the Group B strategy insignificantly reduced incidences of LCOS, arrhythmia, sepsis, renal failure, and neurological complications (Table 4). In the standard group, three patients required dialysis or hemofiltration and, on the twenty-eighth postoperative day, one patient died from severe sepsis with multiorgan failure. No patients developed postoperative myocardial infarction. Upon examining the secondary outcomes, the authors found no difference between the groups in ventilator time, length of ICU at 4 (3 to 5) versus 4 (2 to 5) (p=0.577), and hospital stay at 10 (9 to 13) versus 10 (9 to 11), (p=0.201).

Table 1. Characteristics (demographics and comorbidities) in Groups A & B

Demographic data	Group A (n=35)	Group B (n=30)	p-value
Male; n (%)	23 (65.7)	21 (70.0)	0.713
Age (year); mean±SD	74.7±4.0	74.6±4.3	0.599
Height(cm); mean±SD	160.5±6.8	162.6±6.8	0.306
Weight (Kg); mean±SD	59.3±9.7	63.7±4.6	0.006
Diagnosis; n (%)			0.111
Valvular heart disease	11 (31.4)	5 (16.7)	
Coronary heart disease	9 (25.7)	15 (50.0)	
Combined	15 (42.9)	10 (33.3)	
Functional class III/IV; n (%)	13 (37.1)	12 (40.0)	0.600
LVEF (%); mean±SD	60.3±14.7	58.3±15.8	0.635

Demographic data	Group A (n=35)	Group B (n=30)	p-value
EuroSCORE II; mean±SD	4.47±4.53	3.44±2.43	0.673
STS score; mean±SD	3.85±2.46	2.90±1.79	0.120
Recent MI; n (%)	6 (17.1)	5 (16.67)	0.959
Arrythmia; n (%)	6 (17.1)	0 (0.0)	0.017
CKD stage 3/4; n (%)	23 (54.3)	21 (70.0)	0.544
DM; n (%)	10 (28.6)	10 (33.3)	0.460
Hypertension; n (%)	23 (65.7)	21 (70.0)	0.713
DLD; n (%)	10 (28.6)	19 (63.3)	0.050
Old CVA; n (%)	3 (8.6)	0 (0.0)	0.101

SD=standard deviation; LVEF=left ventricular ejection fraction; MI=myo-cardial infarction; CKD=chronic kidney disease; DM=diabetes mellitus; DLD=dys-lipidemia; CVA=cerebrovascular disease

Table 2. Perioperative data in Groups A & B

Perioperative data	Group A (n=35)	Group B (n=30)	p-value
Operative type; n (%)			0.88
Valvular surgery	14 (40.0)	6 (20.0)	
Coronary artery bypass surgery	8 (22.8)	14 (46.7)	
Combined	13 (37.2)	10 (33.3)	
CPB time (minute); mean±SD	160.8±65.0	152.7±59.6	0.457
Aortic cross clamp time (minute); mean±SD	101.3±39.7	87.9±36.2	0.098
Estimated blood loss (mL); mean±SD	814.0±461.6	639.2±279.1	0.133
Blood transfusion* (unit); median [IQR]	2 [1 to 3]	1 [0 to 2]	0.137
Peak TNT (ng/L); median [IQR]	841 [619 to 1,210]	848 [619 to 1,210]	0.350
Max VIS score; median [IQR]	2.5 [1.4 to 5.66]	2.12 [1.8 to 4.1]	0.438

SD=standard deviation; IQR=interquartile range; CPB=cardiopulmonary bypass; TNT=high sensitivity troponin T; VIS score=vasoactive inotropic score

* Blood transfusion unit about 300 to 500 mL

Table 3. Study outcomes following cardiac output-guided hemodynamic therapy

Study outcome	Group A (n=35)	Group B (n=30)	p-value
30 days composite endpoint; n (%)	22 (62.9)	14 (46.7)	0.145
LCOS; n (%)	13 (37.1)	9 (30.0)	0.366
Arrhythmia; n (%)	14 (40.0)	6 (20.0)	0.082
Renal failure; n (%)	10 (28.6)	6 (20.0)	0.424
Neurological complications; n (%)	7 (20.0)	5 (16.7)	0.492
Sepsis; n (%)	4 (11.4)	1 (3.3)	0.222
Died; n (%)	1 (2.9)	0 (0.0)	0.351
Ventilator time (hour); median [IQR]	16 [13 to 19]	16 [4 to 17]	0.454
Length of ICU stay (days); median [IQR]	4 [3 to 5]	4 [2 to 5]	0.577
Length of hospital stay (days); median [IQR]	10 [9 to 13]	10 [9 to 11]	0.201

IQR=interquartile range; LCOS=low-cardiac-output syndrome; ICU=intensive care unit

$p<0.05$ is considered significant

Discussion

The present study investigated the effect of perioperative cardiac output-guided hemodynamic therapy, which aids in optimizing fluid to maintain hemodynamics and prevent over-resuscitation in the ICU. Although the present study found no significant

difference in reducing overall complications and hospital LOS, findings varied across other studies. Li et al[8] meta-analyzed nine studies that included 1,148 patients and showed similar to the present study, perioperative or postoperative goal-directed hemodynamic therapy (GDT) effects were no different than those of the standard of care for the overall analysis in cardiac surgery. However, Aya et al[6] analyzed five randomized studies and suggested that preemptive GDT reduced morbidity after cardiac surgery. Osawa et al[5] randomized 126 high-risk cardiac patients to perioperative GDT. They utilized LiDCOrapid (LiDCO, London, United Kingdom) to follow an algorithm to maintain a CI above 3 L/minute/m², slightly higher than the CI in the present study, and they showed reductions in morbidity and hospital LOS. Parke et al[9] randomized 715 cardiac surgery participants to a protocol-guided strategy utilizing FloTrac to monitor SVV to assess the likelihood that the participant was volume-responsive and maintain an SVV lower than 13% by fluid bolus. In that study, there was no significant difference in ICU LOS.

There were potential reasons that the present study results differed from those of the previous studies. First, based on the EuroSCORE II and STS score, septuagenarians in the present study were at immediate risk for cardiac surgery, which lowers mortality and morbidities than higher risk. Giglio et al[7] suggested that treatment through monitoring significantly reduced mortality even when the control event rate was greater than 10% of a high-risk STS score. Second, the present study used an algorithm to optimize fluid therapy before maintaining a target CI lower than the previous studies. This algorithm optimized hemodynamic support, resulting in reduced target organ damage, and prevented patients from receiving supranormal resuscitation, demonstrated to worsen the outcomes in the critically ill. Third, although the hemodynamic device used the present study was different from the other studies, FlowTrac provided continuous arterial waveform analysis and was less operator-dependent than echocardiography. Furthermore, patients with hemodynamic instability were given echocardiography for evaluation and management, potentially introducing detection bias. Yet another reason could be within the findings of the GRICS trial[11], which suggested the importance of cardiac output-guided hemodynamic therapy timing, particularly the "golden hours," the first eight hours following cardiac surgery. In the present study, the protocol was started immediately after ICU admission and discontinued after extubation. The present study timing may have reduced SVV accuracy, which relied on mechanical ventilation having a constant tidal volume.

The present study showed similar outcomes in ventilator time, ICU, and hospital stay depending on both availability of ICU beds and the timing of judging a patient fit for discharge from the ICU and hospital. Osawa et al[5] showed reductions in ICU and hospital LOS. Conversely, Parke et al[9] found no significant difference. Although studies showed lower fluid therapy, blood transfusion, and inotropic support requirements during the ICU stay in the GDT group, these reductions in the studies may have been done to reduce the cost to hospitals and the healthcare system[12]. A study showing how these may relate to cost-effectiveness should be further investigated.

The present study contained limitations. First, the study was non-randomized and single center. This limited to smaller sample size than the previous studies. In addition, this was an in-house protocol with limited external validity. Finally, although the monitoring exhibited the parameters, optimized algorithms were not currently available. In the future, multimodal monitoring protocols facilitating earlier problem detection and further appropriating fluid and inotropic management will be required.

The present study was completed on time, and there was no loss to follow-up.

Conclusion

The findings in this present study suggest that cardiac output-guided hemodynamic therapy utilizing SVV, and the CI insignificantly reduce 30-day complications compared to the conventional treatment. The present study also found no difference in length of ICU and hospital stay.

What is already known on this topic?

Cardiac monitoring was applied to optimize hemodynamics in perioperative and critical patients. However, studies shown broadly efficient outcome because of various protocols and instruments.

What this study adds?

This report shown beneficial effects of cardiac output-guided hemodynamic therapy to improve post-operative outcome although these were insignificant differences in outcome to conventional treatment. These findings support this protocol recommended in patients at risk of LCOS.

Conflict of interest

The authors declare that they have no conflict of interest.

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